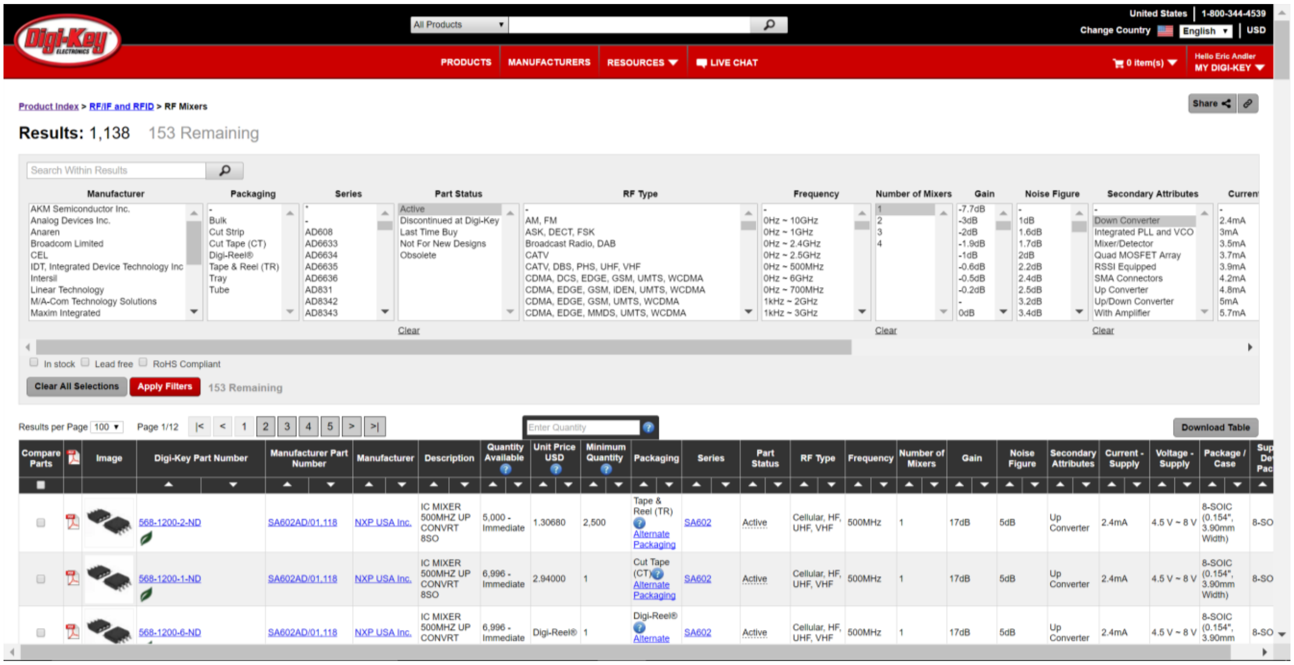
Application Note
Initial Paper Design Process
FMCW Radar for EEC 134 Quarter 2
By Eric Andler

Choosing components for your first RF system is a daunting task. Every component has a long list of attributes that must compliment all the other parts of your system in very specific ways. Often one can be mid-stream in the decision-making process and find that an earlier 'work around' has cascaded into a series of much larger, more difficult problems to overcome. Perhaps the largest waste of time in the initial design phase is to make choices on components in a random order where one oversight can lead to having to take several steps backwards. This note is intended to extol a few lessons learned by someone who has just completed the process of a full design. The initial design phase is extremely important and should be approached with a lot of careful thought. This is especially true in the very short amount of time available in implementation of your design during a ten week course. By approaching this design phase in a systematic manner, confusion and back tracking can be kept to a minimum. This allows for more time in implementation, debugging and optimization. This application note will focus less on the important properties to look for in each component (i.e. 1PdB in amplifiers or conversion gain in mixers). Those aspects are covered in depth during quarter one lectures. Instead this note will focus on an effective strategy for the order in which component decisions should be made.

A Note on Searching Mouser, DigiKey, Mini-circuits

When looking for components on websites such as Mouser, Digi-Key, or Mini-Circuits, I cannot emphasize enough the use of filters in the search functions. There are often thousands (even hundreds of thousands!) of components in a single category. It may seem tedious at first because many of the filter categories are not standardized. For instance, looking for components that use 5 Vcc will have in the filter category +5 Vcc, 4.5 – 5.25 Vcc, 4.2 – 5.3 Vcc and a lot of other variations. Ctrl-left click is your friend here, select all of the ones that apply. The few minutes it takes to filter your results correctly and completely will save a lot of time searching later. One quirk about Digi-Key specifically is to make sure you chose 'active' status filter.



Product Index > RF/IF and RFID > RF Mixers

Results: 1,138 153 Remaining

Manufacturer: AKM Semiconductor Inc., Analog Devices Inc., Anaren, Broadcom Limited, CEL, IDT, Integrated Device Technology Inc, Intersil, Linear Technology, M/A-Com Technology Solutions, Maxim Integrated

Packaging: -, Bulk, Cut Strip, Cut Tape (CT), Digi-Reel®, Tape & Reel (TR), Tray, Tube

Series: *, -, AD608, AD6633, AD6634, AD6635, AD6636, AD831, AD8342, AD8343

Part Status: Active (selected), Discontinued at Digi-Key, Last Time Buy, Not For New Designs, Obsolete

RF Type: -, AM, FM, ASK, DECT, FSK, Broadcast Radio, DAB, CATV, CATV, DBS, PHS, UHF, VHF, CDMA, DCS, EDGE, GSM, UMTS, WCDMA, CDMA, EDGE, GSM, iDEN, UMTS, WCDMA, CDMA, EDGE, GSM, UMTS, WCDMA, CDMA, EDGE, MMDS, UMTS, WCDMA

Frequency: -, 0Hz ~ 10GHz, 0Hz ~ 1GHz, 0Hz ~ 2.4GHz, 0Hz ~ 2.5GHz, 0Hz ~ 500MHz, 0Hz ~ 6GHz, 0Hz ~ 700MHz, 1kHz ~ 2GHz, 1kHz ~ 3GHz

Number of Mixers: 1 (selected), 2, 3, 4

Gain: -7.7dB, -3dB, -2dB, -1.9dB, -1dB, -0.6dB, -0.5dB, -0.2dB, -, 0dB

Noise Figure: -, 1dB, 1.6dB, 1.7dB, 2dB, 2.2dB, 2.4dB, 2.5dB, 3.2dB, 3.4dB

Secondary Attributes: -, Down Converter (selected), Integrated PLL and VCO, Mixer/Detector, Quad MOSFET Array, RSSI Equipped, SMA Connectors, Up Converter, Up/Down Converter, With Amplifier

Curren: -, 2.4mA, 3mA, 3.5mA, 3.7mA, 3.9mA, 4.2mA, 4.8mA, 5mA, 5.7mA

☐ In stock ☐ Lead free ☐ RoHS Compliant

153 Remaining

Results per Page 100 ▾ Page 1/12 |< < 1 2 3 4 5 > >|

Compare Parts		Image	Digi-Key Part Number	Manufacturer Part Number	Manufacturer	Description	Quantity Available	Unit Price USD	Minimum Quantity	Packaging	Series	Part Status	RF Type	Frequency	Number of Mixers	Gain	Noise Figure	Secondary Attributes	Current - Supply	Voltage - Supply	Package / Case	Sup De Pac
☐			568-1200-2-ND	SA602AD/01,118	NXP USA Inc.	IC MIXER 500MHZ UP CONVRT 8SO	5,000 - Immediate	1.30680	2,500	Tape & Reel (TR) Alternate Packaging	SA602	Active	Cellular, HF, UHF, VHF	500MHz	1	17dB	5dB	Up Converter	2.4mA	4.5 V ~ 8 V	8-SOIC (0.154", 3.90mm Width)	8-SO
☐			568-1200-1-ND	SA602AD/01,118	NXP USA Inc.	IC MIXER 500MHZ UP CONVRT 8SO	6,996 - Immediate	2.94000	1	Cut Tape (CT) Alternate Packaging	SA602	Active	Cellular, HF, UHF, VHF	500MHz	1	17dB	5dB	Up Converter	2.4mA	4.5 V ~ 8 V	8-SOIC (0.154", 3.90mm Width)	8-SO
☐			568-1200-6-ND	SA602AD/01,118	NXP USA Inc.	IC MIXER 500MHZ UP CONVRT	6,996 - Immediate	Digi-Reel®	1	Digi-Reel® Alternate	SA602	Active	Cellular, HF, UHF, VHF	500MHz	1	17dB	5dB	Up Converter	2.4mA	4.5 V ~ 8 V	8-SOIC (0.154", 3.90mm	8-SO

Be sure to look closely at packages that components come in. All of your parts will need to be hand soldered, which means that it is better to choose packages that are easier to solder in this manner. Packages such as those on the left, with all of the pins on the underside will be very difficult to mount by hand. You will save a lot of soldering time by choosing components on the right with their pins sticking out in an easy to solder manner.

Find Antenna's First

The antennas will determine the high frequency band width for your entire system. You will want very directional antennas, so pay attention to the lobe shapes. Note that dipole antennas don't work for this application. Be sure to get a decent gain (at least 5 or 6 dBi). Also, don't be afraid to use your coffee cans from quarter one, they are surprisingly very good. For our year most groups ended up using one commercially bought antenna and one coffee can.

Decide on an Operating Voltage (Vcc)

Make that decision now and stick with it. +5V or +3.3V are most common voltages available. It is probably best to only chose one of those and try not to mix. Using diferent bias voltages throughout your system will probably just needlessly overcomplicate your design for now. Both +5V and +3.3V have their advantages and drawbacks. +5 V is slightly more common, but you should be able to find everything you would need at +3.3V. Obviously using +3.3V should reduce the system power consumption. There are a lot of components that use bi-polar voltages, such as +/- 5V. This is especially true for the baseband components (baseband subsystem not covered in this note). Again, many advantages and drawbacks to unipolar vs bi polar.

Design Transmitter

The first component of the transmitter you will want to find is the VCO. This is a very important part of your system. Be sure that the VCO will output the proper frequencies, which is dictated by your antennas. You will also want to check the Vtune values for those frequencies and make sure that these would be easy to make into a triangle wave with your function generator. Next you will want to find an attenuator and a power splitter. These are fairly straight forward. Next you will want to find a good high frequency amplifier. Paying attention to linearity is perhaps more important for the transmitter amplifier than any other amplifier. It may be worth the extra money and power here to get the amplifier with highest linearity here. You'll be shooting for an overall output power from your transmitter of at least 10 dBm. Really 15 – 20 dBm would be more ideal.

Link Budget and Power Received Calculations

You will want to use some sort of cascade analysis tool on both your transmitter and receiver. Analog Devices offers a free software named ADsimRF (download here). Note that this program can be a bit buggy on Windows 10, mostly it doesn't often save very well. It worked fine for our group, but may be worth the effort of searching for a different software. These cascade analyses should let you know if you are working close to non-linearity of your amplifiers, and give you an idea of what the power will be at each component.

Once you've used the cascade analysis on the transmitter and double checked that all components should be working within recommended regions, you will want to do some calculations on the free space path loss. This should give you an idea on the power you can expect to be received. Here you should use the Friis' formula for path loss.

$$P_r = P_t \frac{G_t G_r \lambda^2}{(4\pi R)^2}$$

Here P_r is power receiver, P_t is power transmitted, G_t and G_r is antenna gain, λ is operating wavelength, and R is distance to object.

To see if the transmitter is sending enough power to reach your desired maximum distance, you will want to solve the Friis' formula for R. For P_r you will want to use the minimum received power that could be 'read' by your system. A good number to use is the thermal noise floor. Noise floor at room temperature is easy to solve. It is approximately:

$$-174 + 10\log(BW)\ (dBm)$$

Here BW is the operating bandwidth of your *entire* system. For your radar system, this means take the bandwidth of your low pass filter at the end of your baseband system. For quarter 1 system this would be 15 KHz (which gives a noise floor of -132 dBm).

Design Receiver

This is perhaps the part of your initial design phase that will take the most trial and error. It requires a lot of plugging in different components and re-checking the overall system. The cascade analysis tool becomes very important here.

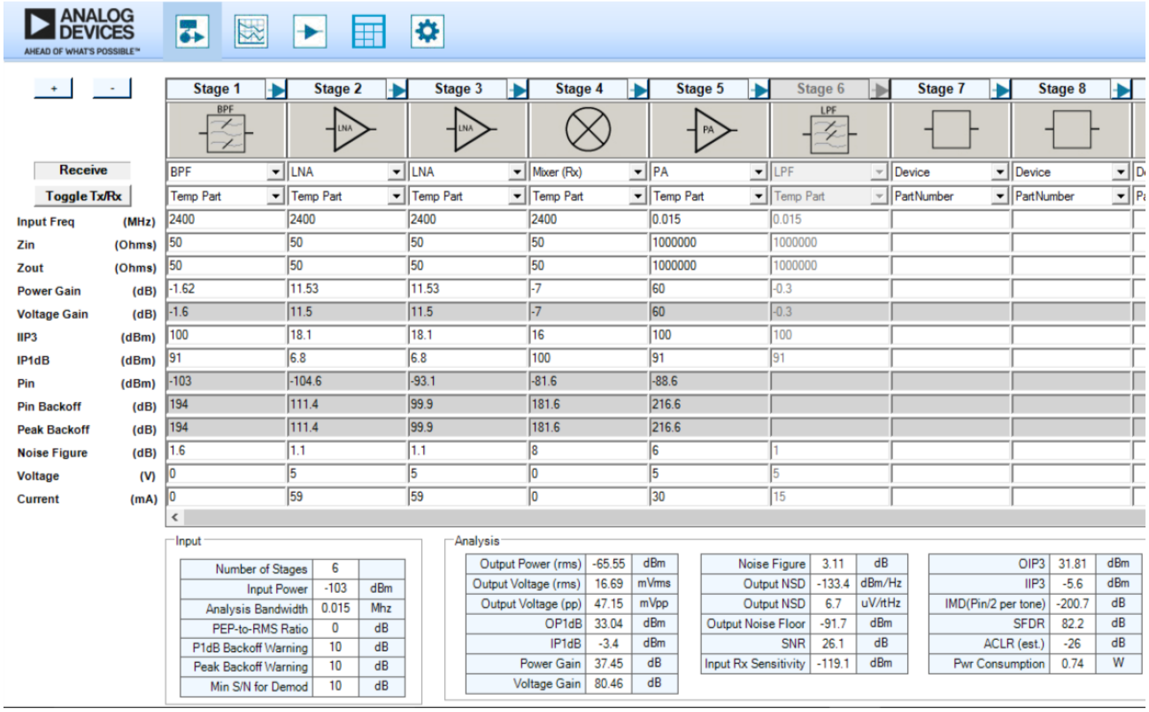
First thing you may want to do is write a MATLAB script that calculates the free space path loss at different distances, especially your minimum and maximum operating distances. Here is a simple one that we wrote:

```
Rmax = 60;     %Max target range (m)
Rmin = 1;      %Min target range (m)
s = .09;       %target surface area (m^2)
G = 6.58;      %Antenna Gain (dBi)
freq = 2.4e9;  %System operating frequency (Hz)
Pt = 15;       %Power out of transmitter (dBm)
l = 3e8 / freq;      %operating wavelength
G = 10^(G/10);       %convert gain to SI units (W)
Pt = 10^((Pt-30)/10);  %convert power to SI units (W)

%power received with target at 1 meter
Prmin = Pt*(G^2)*(l^2)*s / (64*(pi^3)*(Rmax^4));
Prmin = (10* (log10(Prmin))) + 30;
disp(Prmin);

%power received with target at 60 meters
Prmax = Pt*(G^2)*(l^2)*s / (64*(pi^3)*(Rmin^4));
Prmax = (10* (log10(Prmax))) + 30;
disp(Prmax);
```

Then you will begin to choose components such as band pass filters, amplifiers, and a mixer.

Plug all the necessary attributes into the cascade analysis tool for each of the components you have chosen. You will want to check the ‘Input Rx sensitivity’ to make sure it is similar to the thermal noise floor that you calculated earlier. In theory, this sensitivity measure is the minimum power that your receiver can detect. Then you will want to plug the minimum and maximum received power numbers you calculated earlier in the MATLAB script. With the cascade tool, you will be able to easily check that all of your amplifiers are operating within their linear regions. You will also want to check the output power and voltages. For most ADC’s you will want and output voltage to be on the order of mVpp. If you are using the soundcard on a computer (such as you did in quarter 1) you will want an output voltage on the order of a few hundred mVpp.

As a side note: be careful when choosing a mixer that the LO power is high enough. This is not covered in the cascade analysis. You will want to check the power coming out of the splitter of your receiver is at or above the minimum power requirement of your mixer. For example, is you chose a +7 dBm mixer, then the power coming out of the splitter needs to be at least +7 dBm.



		Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6	Stage 7	Stage 8
		BPF	LNA	LNA	Mixer (Rx)	PA	LPF	Device	Device
		Temp Part	Temp Part	Temp Part	Temp Part	Temp Part	Temp Part	PartNumber	PartNumber
Input Freq	(MHz)	2400	2400	2400	2400	0.015	0.015		
Zin	(Ohms)	50	50	50	50	1000000	1000000		
Zout	(Ohms)	50	50	50	50	1000000	1000000		
Power Gain	(dB)	-1.62	11.53	11.53	-7	60	-0.3		
Voltage Gain	(dB)	-1.6	11.5	11.5	-7	60	-0.3		
IIP3	(dBm)	100	18.1	18.1	16	100	100		
IP1dB	(dBm)	91	6.8	6.8	100	91	91		
Pin	(dBm)	-103	-104.6	-93.1	-81.6	-88.6			
Pin Backoff	(dB)	194	111.4	99.9	181.6	216.6			
Peak Backoff	(dB)	194	111.4	99.9	181.6	216.6			
Noise Figure	(dB)	1.6	1.1	1.1	8	6	1		
Voltage	(V)	0	5	5	0	5	5		
Current	(mA)	0	59	59	0	30	15		

Input

Number of Stages	6	
Input Power	-103	dBm
Analysis Bandwidth	0.015	Mhz
PEP-to-RMS Ratio	0	dB
P1dB Backoff Warning	10	dB
Peak Backoff Warning	10	dB
Min S/N for Demod	10	dB

Analysis

Output Power (rms)	-65.55	dBm
Output Voltage (rms)	16.69	mVrms
Output Voltage (pp)	47.15	mVpp
OP1dB	33.04	dBm
IP1dB	-3.4	dBm
Power Gain	37.45	dB
Voltage Gain	80.46	dB

Noise Figure	3.11	dB
Output NSD	-133.4	dBm/Hz
Output NSD	6.7	uV/rtHz
Output Noise Floor	-91.7	dBm
SNR	26.1	dB
Input Rx Sensitivity	-119.1	dBm

OIP3	31.81	dBm
IIP3	-5.6	dBm
IMD(Pin/2 per tone)	-200.7	dB
SFDR	82.2	dB
ACLR (est.)	-26	dB
Pwr Consumption	0.74	W